A WESTERN ATLANTIC VORTEX SEEN BY TIROS I

J. B. JONES, MAJOR, USAF

Air Weather Service Member, Meteorological Satellite Laboratory, U.S. Weather Bureau, Washington, D.C.

[Manuscript received April 14, 1961; revised June 29, 1961]

ABSTRACT

TIROS I observed an extratropical cyclone near Bermuda on three occasions in early May 1960 during the last 86 hours of the life cycle of the storm. A study of this case was undertaken with three objectives in mind: (a) to describe interesting features of the organization manifested in the cloud patterns and compare these with conventional analyses; (b) to present a subjective interpretation of some of the cloud images and discuss the criteria which form the basis for interpretation; and (c) to show examples of practical application of these pictures of the storm to routine frontal analysis and nephanalysis.

1. INTRODUCTION

During early May 1960, TIROS I took pictures of a small extratropical vortex located in the western Atlantic between Bermuda and the southeastern United States. Pictures were obtained during the mid-afternoon on May 5, 7, and 8. On May 6 the orbital passes over the region were too far east or west of the vortex for the satellite to view the associated cloud patterns. Included in this paper are a brief synoptic history of the storm, a description and subjective interpretation of the cloud images, a brief discussion of the apparent relation between the cloud patterns and conventional analyses, and finally a demonstration of the practical utility of the cloud pictures obtained by a satellite.

In recent months, storms observed by TIROS I over the eastern Pacific Ocean, the central United States, and the northeastern Atlantic Ocean have been studied [1, 7, 12, 15]. Some of these studies deal essentially with a single observation of the storm [1, 12]. In other cases successive views of the same system have permitted a study of persistent and transient features of the associated cloud patterns over time intervals varying from 100 minutes to approximately 24 hours [7, 15]. For the case presented in this paper, a fortuitous set of circumstances provided pictures of the same storm at 48- and 24-hour intervals over a 4-day period, recording on film the degeneration of a vigorous cyclone.

2. SYNOPTIC HISTORY

Indications of a wave formation on the polar front in the Atlantic immediately east of Florida appeared on the NAWAC surface analysis for 0000 GMT, May 3, 1960 (fig. 1a). During the next 72 hours, the wave continued to develop and apparently reached maximum intensity at about 0000 GMT, May 6 (figs. 1b-d). Subsequently the low center retrograded (figs. 1e-f), the associated frontal system became diffuse and ill defined, and finally during the period 0000 GMT to 1200 GMT May 9, the vortex filled and disappeared (figs. 1g-h).

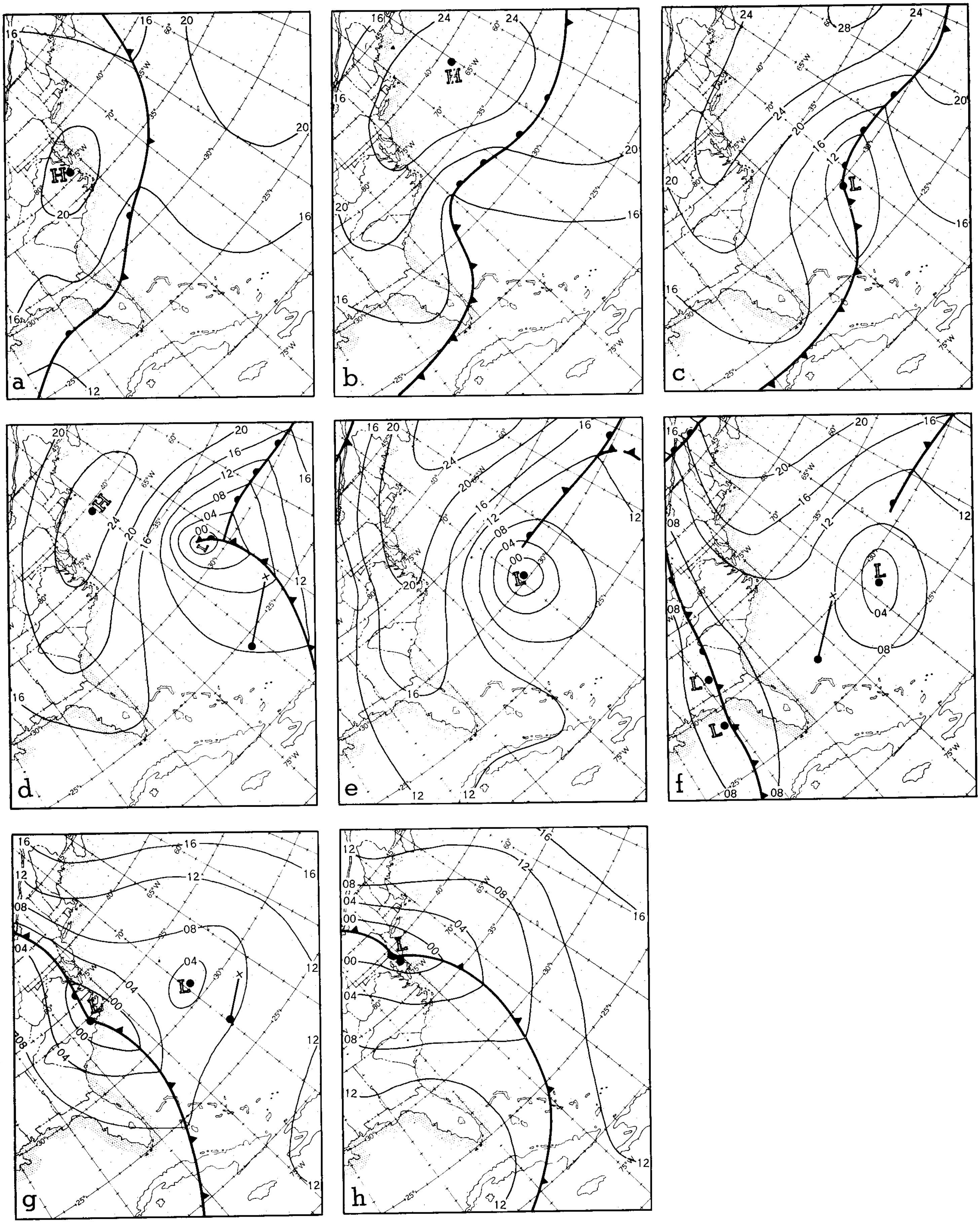
3. THE PICTURES

ORGANIZATION

The storm was first viewed by TIROS on May 5 near 2200 GMT as it was reaching maximum intensity (fig. 2a). Photographs obtained near 2200 GMT, May 7 and 2100 GMT, May 8 show the cloud distribution in and near the vortex as the storm center weakened (figs. 3a, 4a). Satellite subpoints and principal points in the area viewed in these pictures are shown in figure 1, maps d, f and g, respectively.

Perhaps the most striking feature of the photographs is the degree of organization manifested by the spiral bands of clouds. These bands, which converge toward the "cloud crest" at A, give the viewer an immediate impression of a cyclonic circulation. Comparing figures 2a and 4a, it is apparent that in that length of time the number of bands associated with the storm decreased and the "crest" at A became more broken—a likely sequence of events considering the synoptic history of the vortex (fig. 1). However, it is interesting to note that even as the Low filled, the general pattern, or "cyclone print" [6], of the storm persisted throughout the period of decay. The persistence of the pattern between figures 3a and 4a, a time span of 23 hours, is quite remarkable.

The spiral bands associated with the vortex display a considerable dimensional variation—apparently unrelated to the vigor of the storm center. For example, the band DD′, figure 2a, measures about 600 n.mi. in length and varies in width from 15 to 30 n.mi. Close inspection of this band on the original positive transparency shows the main band to be composed of a number of smaller bands or streets. These component streets appear to vary in


a
b
c
d
e
f
g
h

width from 3 to 10 n.mi.[1] The dimensional spectrum is displayed more graphically in figure 4a by comparison of bands II′ and JJ′. The latter is about 400 n.mi. long and varies from 15 to 60 n.mi. in width. The narrow band at II′, which measures about 2 n.mi. in width, appears to be continuous over a span of about 240 n.mi. It is conceivable that even narrower bands actually existed which are not visible in the photograph due to the limited resolving capability of the vidicon system [5].

In addition to the banded structure apparent in the pictures, another interesting feature is seen in figure 3a along FF′. Here the clouds are arrayed in the form of a chain with the cloud elements which form the links surrounding relatively cloud-free areas. Each link measures approximately 60 n.mi. in diameter with the inner, relatively cloud-free area measuring about 40 n.mi. Patterns similar to this "daisy chain" arrangement have been seen in photographs from the Atlas nose cone on August 11, 1959 [2], and in many pictures taken by TIROS [9]. The significance of this pattern is not immediately apparent though it may suggest the existence of a meso-scale convective regime.

The spiral banded structure of tropical storms has been well documented in the literature [4]. Pictures taken by TIROS I indicate that this banded organization may also be a common feature of the mature extratropical cyclone [7, 15, 6]. The organization apparent in the vigorous extratropical storm (fig. 2a) bears a striking resemblance to that of the typhoon seen near Australia on April 10 by TIROS I [13]. A mirror image of the typhoon is shown in figure 5 to facilitate comparison with the picture in figure 2a. (The mirror image reverses the clockwise sense of the Southern Hemisphere cyclonic circulation.) The relative positions and characteristics of the cloud images seen at A, C, and E as well as the spiral bands are features common to both storms.

SUBJECTIVE INTERPRETATION—CRITERIA AND COMPARISON WITH CONVENTIONAL DATA

Information derived directly from the pictures permits a reasonably accurate and detailed analysis of the organization and distribution of the clouds over most of the viewed area [5]. Information required to complete the description or nephanalysis of the picture—cloud form or type, probable thickness, and probable cloud top heights—must presently be subjectively inferred from the characteristics of the cloud images. Inferences drawn from synoptic models, and from relative brightness,[2] texture, size, shape, and edge characteristics of the cloud images presently form the somewhat tenuous basis for this subjective interpretation [1, 15].

Abbreviated station models showing total sky cover, cloud type, present and past weather, and sferics reports from data available for 0000 GMT on May 6, 8, and 9 are plotted on the appropriate view of the storm in figures 2b, 3b, and 4b for reference in the following interpretation of selected areas of the pictures.

The cloud mass at A in figure 2a, because of its lateral extent and amorphous character is interpreted to be an area of stratiform cloud. The brightness, relative to other cloud images in this picture, and the solid appearance of the area suggest that the clouds are dense, probably overcast and multilayered through the cirrus level. The extreme brightness of the image also suggests the possibility of imbedded convective cloud forms. In contrast, C in figure 2a is a relatively dull, featureless area which gives the impression of rather extensive, thin broken to overcast low stratiform cloud. In general, the spiral bands appear to be composed mainly of cumuliform cloud. This inference is drawn primarily from the small, relatively bright and sharply defined cloud masses within the bands (figs. 3a and 4a) and through reference to cyclone models. The band at JJ′ in figure 4a is reminiscent of the instability lines frequently observed in northwesterly flow to the rear of a cyclone center.

The small, bright, sharply defined cloud masses at E in figure 2a give the impression of strong cumulus activity. This impression is heightened by the thin veil-like cloud at E′ giving the appearance of cirrus spissatus being blown off tops of cumulonimbus.

The scarcity of surface observations from the area of the vortex (figs. 2b, 3b, 4b) prevents a more than superficial comparison of conventional observations and those made by the satellite. The subjective interpretations of cloud form based on criteria mentioned earlier can be neither completely supported nor rejected from the conventional data at hand. Data available in this case tend to show that the relatively brighter areas in the pictures contain clouds and weather generally associated with vertical development or deep cloud layers: (fig. 2a: moderate showers at A, showers and swelling cumulus at B′, showers at D, and towering cumulus below and to the left of E; figure 3a: towering cumulus near F′ and above and to the left of F, towering cumulus and showers at G, squalls at H, and cumulonimbus at H′; figure 4a:

[1] These details, available in the film transparency, may not reproduce clearly in the illustration. Much of the picture is in the local twilight zone resulting in low contrast within the area of the photograph. Local time within the pictured area varies from about 1700 hours on the left to about 1845 on the right where the horizon appears to "melt away" in darkness.

[2] Relative brightness alone admittedly can be misleading. Neiburger [11] has shown that relatively thin stratus can be highly reflective and Fritz [8] shows that the albedo for a given cloud type can vary over a significant range. On the other hand, preliminary results of investigations by Conover and by member of the Meteorological Satellite Laboratory show that deep cloud masses—large cumuli and cloud masses producing steady rain—frequently correspond to the brighter images in the photograph.

←

Figure 1.—Synoptic history of the west Atlantic vortex. NAWAC surface analyses for (a) 0000 GMT, May 3 1960; (b) 0000 GMT, May 4, 1960; (c) 0000 GMT, May 5, 1960; (d) 0000 GMT, May 6, 1960 with satellite subpoint (●) and picture principal point (+), for the picture in figure 2a; (e) 0000 GMT, May 7, 1960; (f) 0000 GMT, May 8, 1960 with satellite subpoint and picture principal point, for the picture in figure 3a; (g) 0000 GMT, May 9, 1960 with satellite subpoint and picture principal point, for the picture in figure 4a; and (h) 1200 GMT, May 9, 1960.

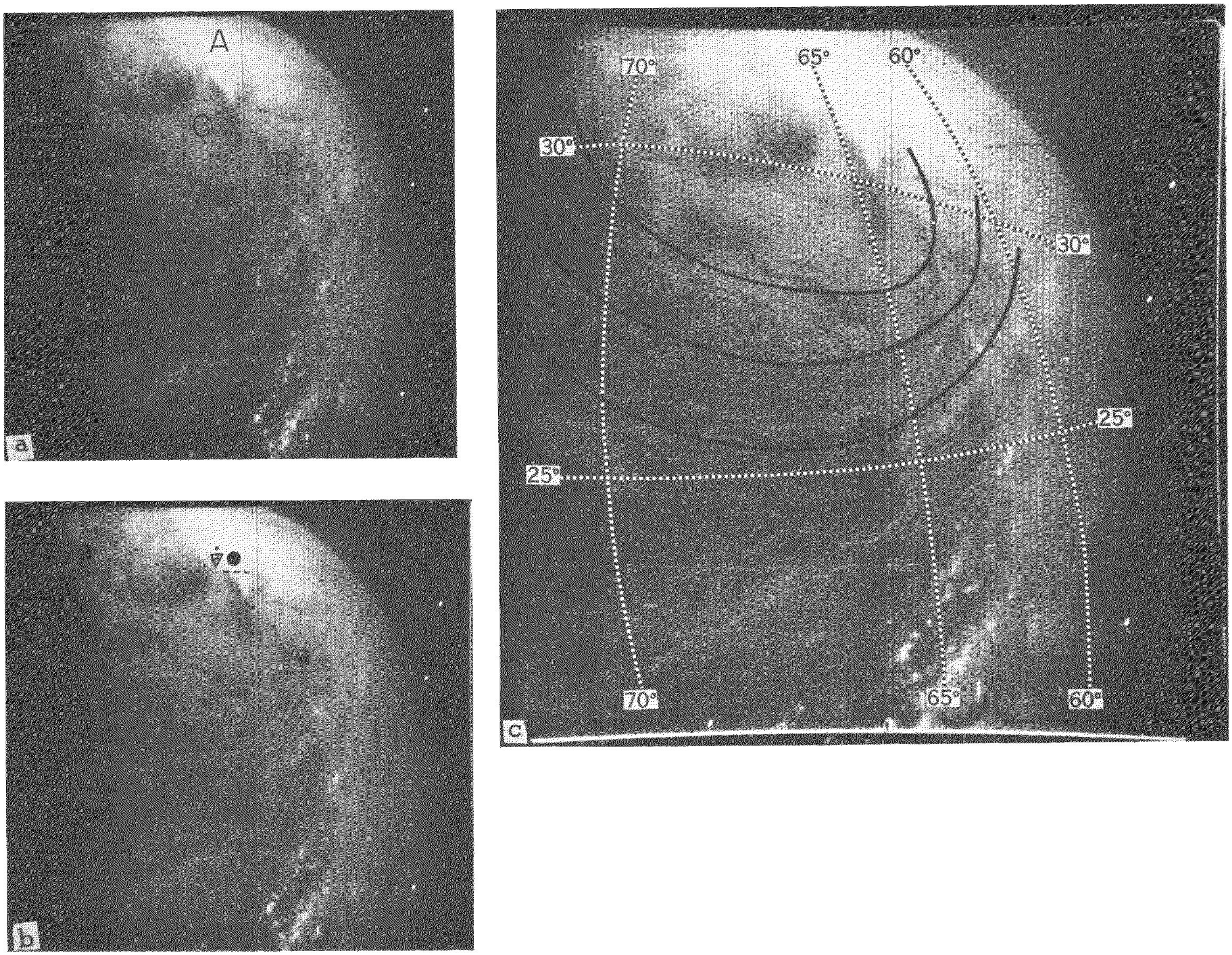


FIGURE 2.—(a) View of the vortex at 2200 GMT, May 5, 1960; (b) Same view with superimposed abbreviated station models from surface data for 0000 GMT, May 6, 1960; (c) Same view with latitude-longitude grid, and 1000–700-mb. mean flow superimposed.

altocumulus—altostratus at A and modreate to strong sferics returns at L). On the other hand, reports of fog, stratus, and stratocumulus—cloud forms and weather indicating little vertical thickness—appear to correspond to the relatively dark, amorphous cloud images in the photographs (fig. 2a: B,D′; fig. 3a: F). The report of clear skies at M in figure 4a corresponds to an area of the picture which is nearly black.[3]

4. RELATIONSHIP TO CONVENTIONAL ANALYSES

Kuettner [10] has shown that under certain conditions of stability and vertical wind distribution, cloud bands tend to parallel the direction of the flow in the convective layer. This relationship, if generally associated with cloud patterns identifiable from a satellite, would obviously enhance the meteorological value of the cloud pictures. For purposes of comparison, the mean flow between 1000 mb. and 700 mb., derived graphically from the surface and 700-mb. analyses prepared in NAWAC, is superimposed on the appropriate picture of the vortex in figures 2c, 3c, and 4c. In addition, latitude-longitude grids are superimposed to provide a familiar frame of reference [3]. Accepting the basic analyses as a good approximation of the flow pattern at the chosen levels—keeping in mind the inherent subjectivity—one finds a fair to good correlation between the orientation of the cloud bands to the south and west of the storm center and the mean contours delineating the flow to the rear of the cyclone within the 1000–700-mb. layer.

[3] Deep water normally appears black to the satellite unless specular reflection is present [8].

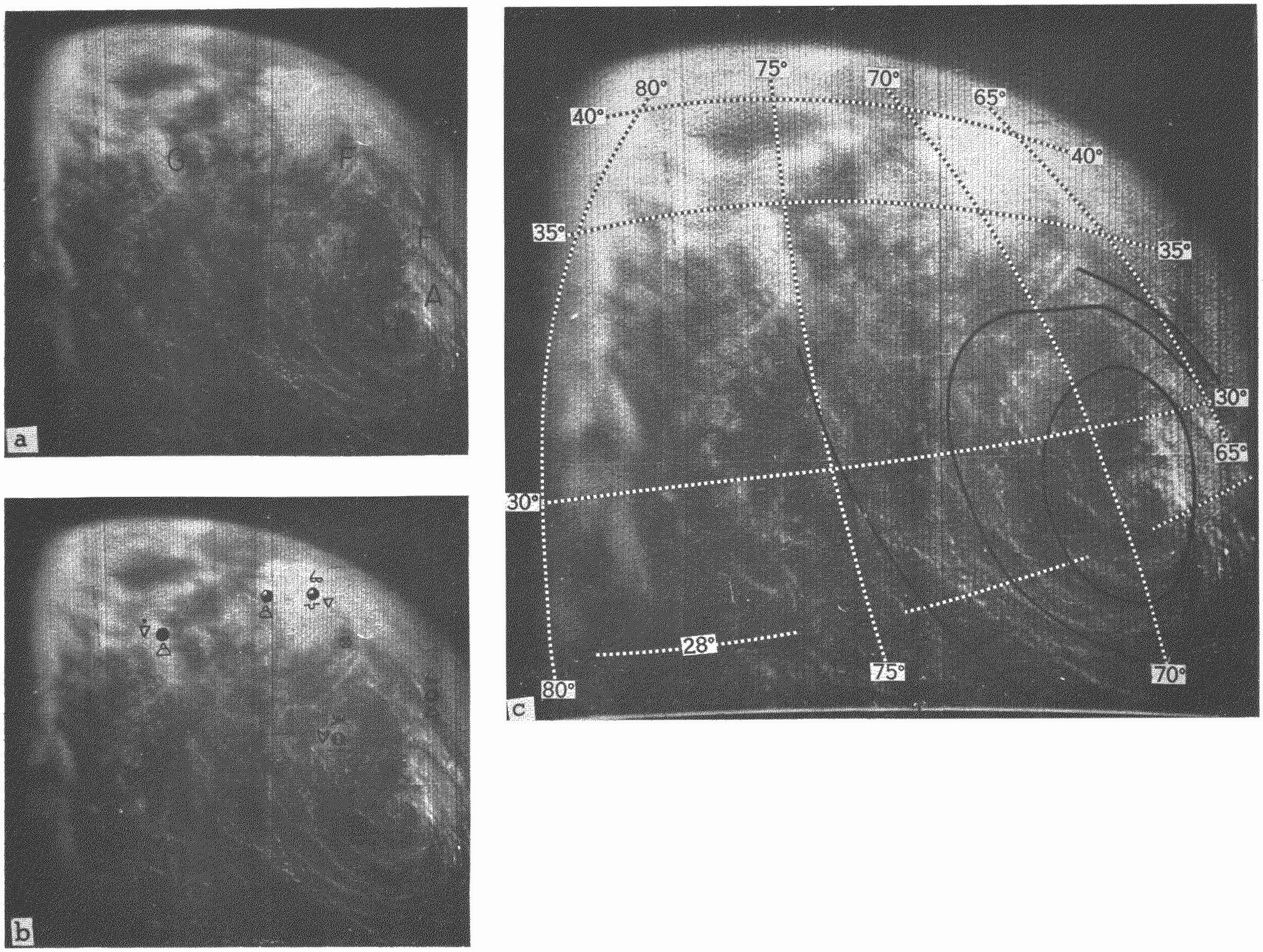


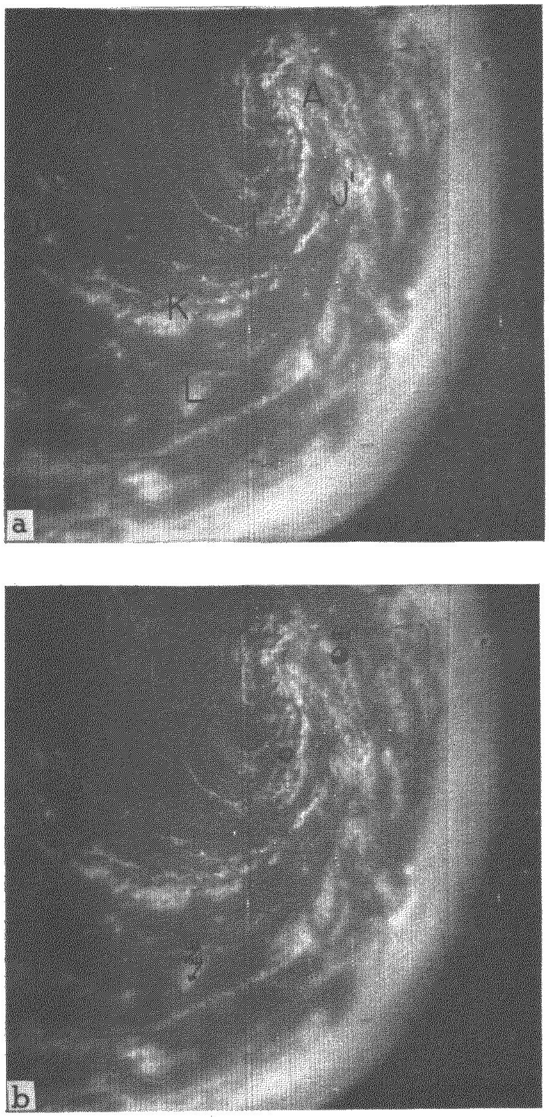
Figure 3.—(a) View of the vortex at 2200 GMT, May 7, 1960; (b) Same view with superimposed surface data for 0000 GMT, May 8, 1960; (c) Same view with latitude-longitude grid, and 1000-700-mb. mean flow superimposed.

5. OPERATIONAL UTILITY OF SATELLITE CLOUD PICTURES

The same lack of conventional weather data which frustrates a comprehensive study of this storm emphasizes the potential of a picture-taking satellite to provide useful observational data from areas where meteorological information in any form is either sparse or nonexistent.

The application of satellite cloud pictures to a routine analysis problem is demonstrated in figure 6. The shaded area in figure 6a reproduces an actual analysis of conventional cloud observations in terms of cloudiness significant for air operations in the middle troposphere. The majority of the data considered in this analysis are valid for 0000 GMT, May 9. The schematic nephanalysis from pictures over much of the same area taken approximately 3 hours earlier by TIROS I on pass 543 (fig. 4 represents one picture from this pass) is superimposed on the conventional analysis in figure 6b [14]. The abbreviated station models in figure 6a represent the total conventional data coverage within the area of "No Significant Cloud." It is apparent that an analyst relying solely on these data could not accurately depict the existing cloud distribution observed by TIROS. Yet it is conceivable that the areas of cumuliform cloud and the southward extension of the middle cloud deck at N in figure 6b are significant to the air operations mentioned above.

This series of pictures also provides an opportunity to apply satellite cloud information to the evaluation of a frontal analysis based on a few conventional observations and, of necessity, to a large extent on continuity. The picture in figure 2a represents the cloud pattern over the



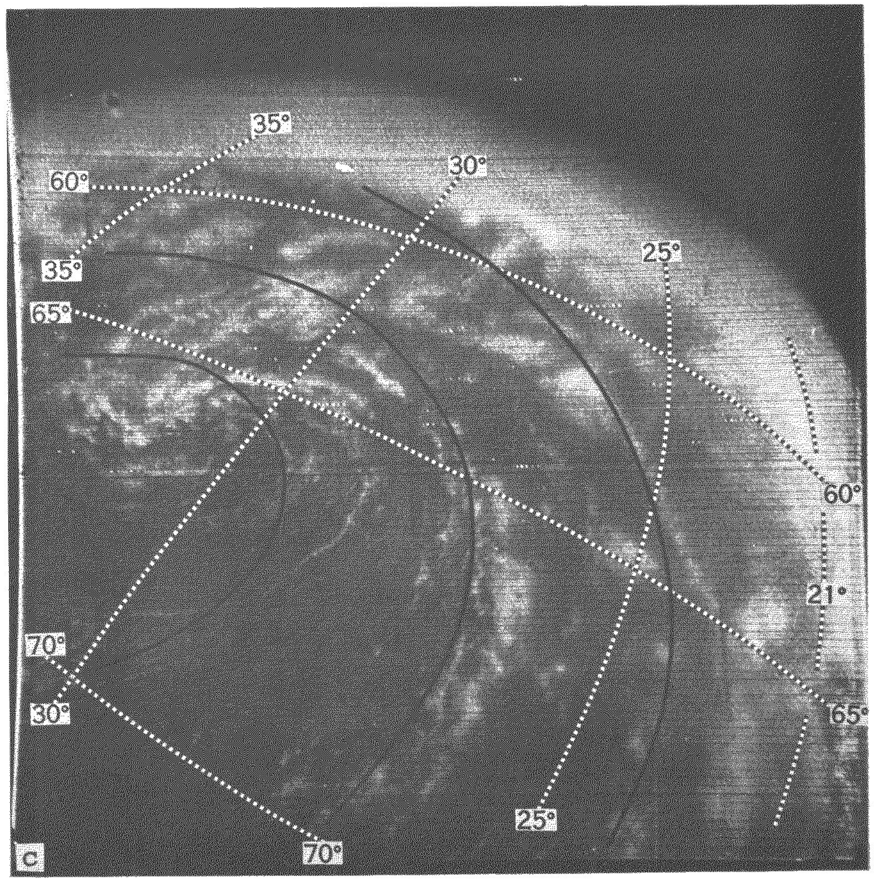


FIGURE 4.—(a) View of the vortex at 2100 GMT, May 8, 1960; (b) Same view with superimposed surface data for 0000 GMT, May 9, 1960; (c) Same view with latitude-longitude grid, and 1000–700-mb. mean flow superimposed.

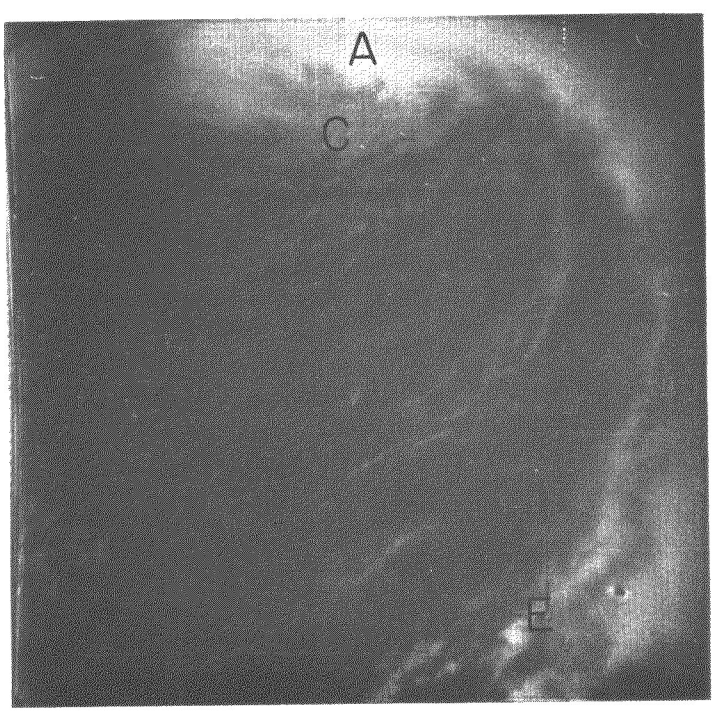


FIGURE 5.—Mirror image of the typhoon viewed by TIROS I near Australia on April 10, 1960 (for comparison of pattern with that of this vortex).

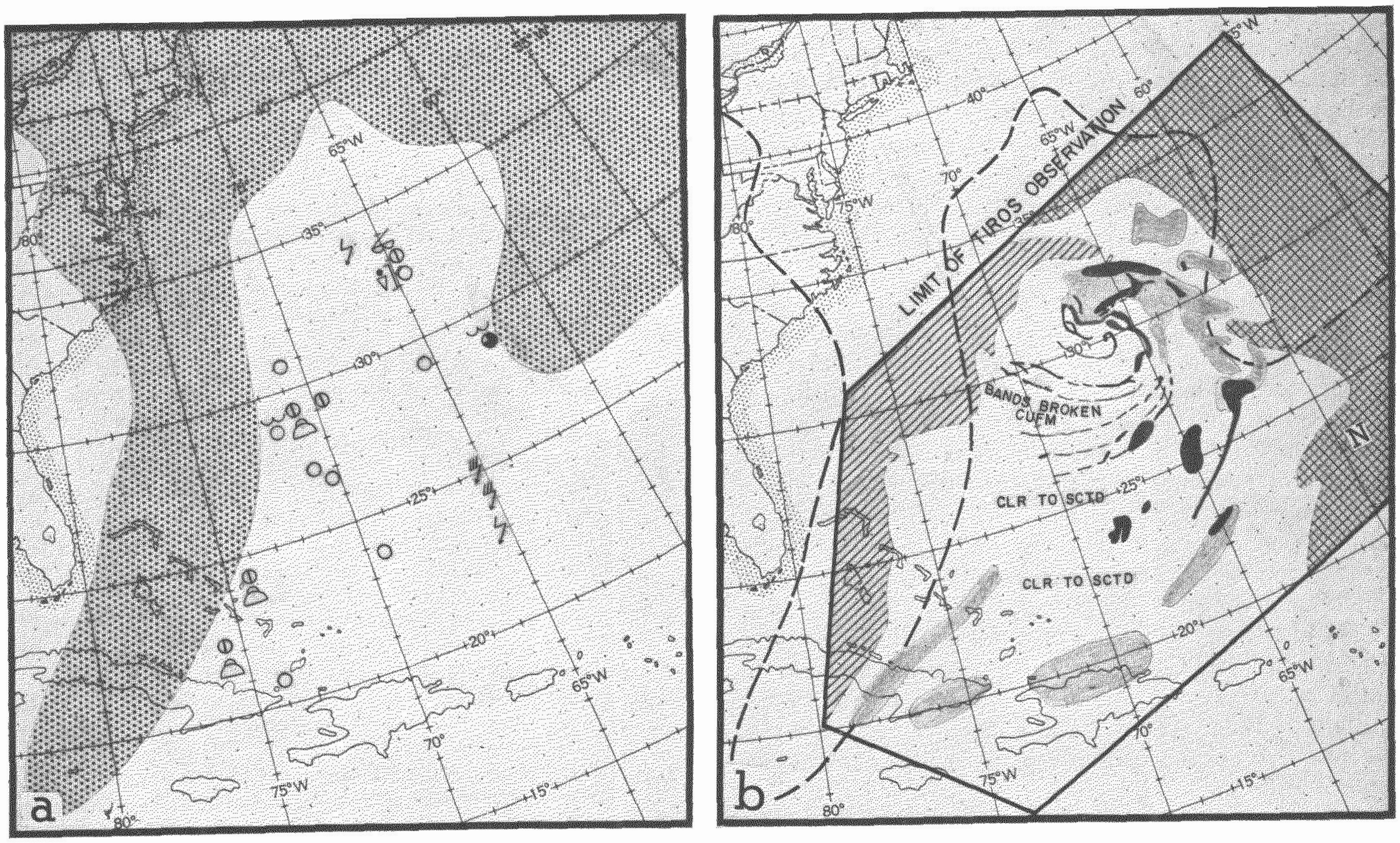


Figure 6.—(a) Nephanalysis of conventional cloud observations for 0000 gmt, May 9, 1960. Stippling shows broken to overcast cloud cover between 10,000 and 20,000 ft., no stippling indicates clear sky or scattered cloud between 10,000 and 20,000 ft. Abbreviated station models show conventional data available in the area of no significant cloud. (b) Nephanalysis made from TIROS I pictures for 2100 gmt, May 8, 1960. Dashed line shows extent of broken to overcast cloudiness on conventional nephanalysis of (a). Single-line hatching indicates broken to overcast clouds, type unknown; cross-hatching broken to overcast, probably mid-stratiform; solid shading indicates broken to scattered, probably large cumuliform; light shading broken to scattered, probably stratiform or small cumuliform.

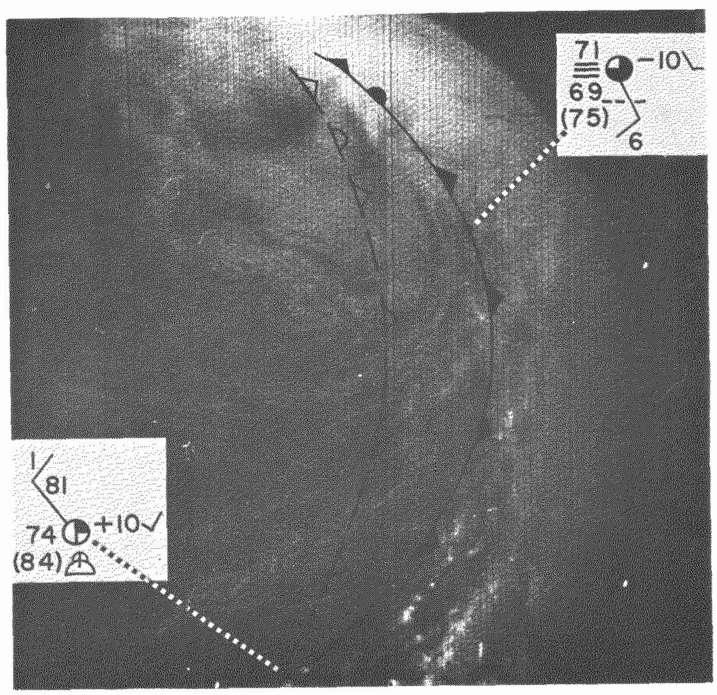


Figure 7.—View of the vortex at 2200 gmt, May 5 showing the NAWAC frontal position for 0000 gmt, May 6 (front with open symbols) with the two ship reports available to the analyst, and a proposed reanalysis of the front based on the conventional reports plus the picture data (front with solid symbols.)

region containing the cold front and vortex at the approximate time of the analysis shown in figure 1d. The conventional frontal analysis for 0000 GMT, May 6 relative to the appropriate cloud photograph is shown in figure 7. A revised frontal analysis based on subjective interpretation of the picture is also shown in figure 7. At its mid-point the amended position of the cold front lies approximately 120 n.mi. to the east of the NAWAC position.

The position suggested by the TIROS picture defines a boundary or zone of transition between two apparently different regimes as manifested by the distribution and organization of the clouds. To the west of this line the clouds are arrayed in spiral bands which tend to converge along the proposed frontal boundary. Immediately to the east of the line, generally broken to overcast conditions prevail except for the few parallel lines of apparently heavy cumulus in the lower right portion of the picture which, as mentioned earlier, are suggestive of squall line activity.

Lack of conventional data does not permit an analytical defense of the TIROS frontal position, and for that matter prevents even an analytical defense of the very existence of the front. Assuming, however, that a frontal discontinuity existed in this region, the TIROS position appears to be the more logical one.

6. SUMMARY

The TIROS pictures of the latter four days of this storm revealed a remarkable persistence in the organization of clouds associated with the vortex. The apparent decrease in numbers of spiral bands and the gradual breakup of the "crest" at A in figures 2, 3, 4 suggest that consecutive observations of the cloud patterns associated with a particular system at regular intervals may provide information regarding day-to-day changes of intensity and stage of development.

In discussing the relationship of the images to the conventional cloud observations, the subjectivity of the interpretation and the limitations thus imposed on practical applications are recognized. In spite of this subjectivity, which is also inherent to some degree in conventional weather observations, this study suggests that TIROS observations provide a basis for logical meteorological analysis in areas where conventional data are sparse or nonexistent.

REFERENCES

1. C. L. Bristor and M. A. Ruzecki, "TIROS I Photographs of the Midwest Storm of April 1, 1960", *Monthly Weather Review*, vol. 88, Nos. 9–12, Sept.–Dec. 1960, pp. 315–326.
2. J. H. Conover and J. C. Sadler, "Cloud Patterns as Seen from Altitudes of 250 to 850 Miles—Preliminary Results," *Bulletin of the American Meteorological Society*, vol. 41, No. 6, June 1960, pp. 291–297.
3. R. C. Doolittle, L. Miller, and I. Ruff, "Geographic Location of Cloud Features," Appendix 1 of "Some Meteorological Results from TIROS I," Staff, Meteorological Satellite Laboratory, U.S. Weather Bureau, in a National Aeronautics and Space Agency Report on TIROS I (in press).
4. G. E. Dunn and B. I. Miller, *Atlantic Hurricanes*, Louisiana State University Press, 1960, 326 pp. (pp. 152–173).
5. C. O. Erickson and L. F. Hubert, "The Identification of Cloud Forms from TIROS I Pictures" MSL Report No. 7, June 1961, (U.S. Weather Bureau manuscript).
6. S. Fritz, " 'Cyclone-Prints' from Satellite (TIROS I)," *INTERAVIA—World Review of Aviation and Astronautics*, vol. 15, 1960, pp. 1384–1385.
7. S. Fritz, "Satellite Cloud Pictures of a Cyclone Over the Atlantic Ocean," *Quarterly Journal of the Royal Meteorological Society* (in press).
8. S. Fritz, "Solar Radiant Energy and its Modification by the Earth and its Atmosphere," *Compendium of Meteorology*, American Meteorological Society, Boston, 1951, pp. 13–33.
9. A. F. Kreuger and S. Fritz, "Cellular Cloud Patterns Revealed by TIROS I," *Tellus*, (in press).
10. J. Kuettner, "The Band Structure of the Atmosphere," *Tellus*, vol. 11, No. 3, Aug. 1959, pp. 267–294.
11. M. Neiburger, "Reflection, Absorption, and Transmission of Insolation by Stratus Clouds," *Journal of Meteorology*, vol. 6, No. 2, Apr. 1949, pp. 98–104.
12. V. Oliver, "A Comparison of a Satellite Nephanalysis with a Conventional Weather Analysis for a Family of Pacific Frontal Storms," "Some Meteorological Results from TIROS I," Staff, Meteorological Satellite Laboratory, U.S. Weather Bureau, in a National Aeronautics and Space Agency Report on TIROS I (in press).
13. "TIROS I Completes Its Mission: TIROS II Readied," *Weatherwise*, vol. 13, No. 4, Aug. 1960, pp. 158–161.
14. W. K. Widger, Jr., "Examples of Project TIROS Data and Their Practical Use," *GRD Research Notes*, No. 38, July 1960.
15. J. S. Winston, "Satellite Pictures of a Cut-Off Cyclone over the Eastern Pacific," *Monthly Weather Review*, vol. 88, Nos. 9–12, Sept.–Dec. 1960, pp. 295–314.